Three-Dimensional Sub-Strip Position Interpolation in Thick Silicon Detectors

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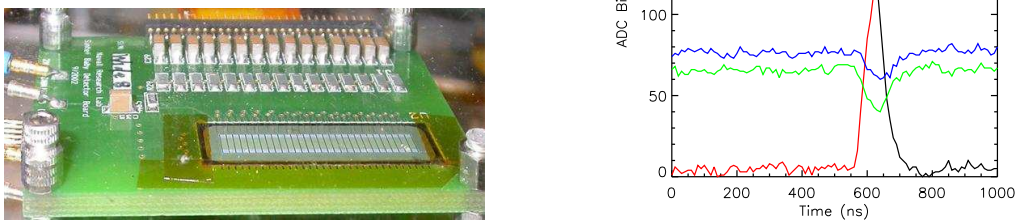
Abstract

We have used flash ADCs to digitize preamplifier signals from a silicon strip detector to yield information about the energy of the interaction as well as its location in three dimensions. The energy is proportional to the size of the signal and the depth to the time difference between signals at the cathode and anode sides of the detector. The lateral interaction location can be determined to less than the width of a strip by measuring the induced pulses in neighboring strips. This work extends results in germanium to thick silicon detectors. At room temperature, the energy resolution is 5 keV FWHM at 122 keV and sub-strip pitch position resolution has been demonstrated.

Digitizing the signal from the preamplifier allows one to measure the location of the gamma ray interaction to less than the strip pitch and measure the depth of the interaction. This has been demonstrated in germanium detectors by multiple groups [1, 2]. This method has now been demonstrated at room temperature in a 2 mm thick silicon detector manufactured by SINTEF [3] The detector is shown in Fig. 1(a).



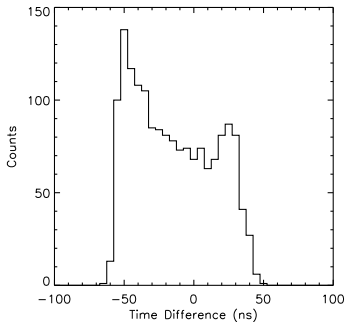
(a) SINTEF Detector

(b) FADC Signals

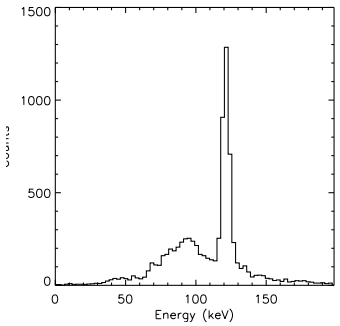
Figure 1: The cathode side of a SINTEF detector is shown in (a) and signals from four strip are shown in (b). The black signal is from the middle, triggered, cathode strip and corresponds to approximately 205 keV. The red signal is one of the anode strips and matches the cathode signal in energy. The blue and green signals are from the strips neighboring the triggered cathode strip.

The detector for this experiment has 30 strips on the cathode with a strip pitch of 0.891 mm and 5 anode strips with the same pitch. eV Products module 5093 preamplifiers were connected to the 35 strips and -700 V were applied to the detector. An x-y position table holding a linearly collimated source was placed over the detector. The beam of collimated gamma rays was aligned parallel to the cathode strips and was 0.26 mm wide FWHM at the detector. The table was scanned to find the beginning and end of a cathode strip near the center of the detector. This strip, its four nearest neighbors, and the middle three anode strips were connected to a VME Struck 3301 Flash ADC [4]. The Struck module can run at 100 MHz and has 14 bit resolution over a voltage range of ± 1 V. The module was set to trigger off of the middle cathode strip. A typical signal from a ^{133}Ba source is shown in Fig. 1(b).

The energy of the signal is calculated by measuring the signal height before and after the rising edge. This yields an energy resolution of 4-5 keV FWHM at 122 keV at room temperature (Fig. 2(b)), comparable to what is seen with typical shapers and ADCs for this detector at room temperature.



(a) Depth



(b) Spectrum

Figure 2: A plot of the time difference between signal collection on the cathode and anode side is shown in (a) and the energy spectrum for ^{57}Co on a cathode strip is shown in (b).

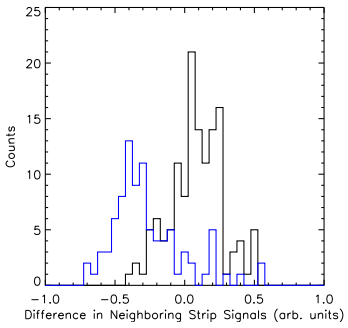


Figure 3: The difference over the sum of the size of the induced signals on neighboring strips for ^{133}Ba for events near the anode side of the detector. The curve in black is near one edge of the strip and the curve in blue is near the opposite edge, a total shift of 0.5 mm. The FWHM of the curves corresponds to 0.4 mm position resolution for a 0.26 mm wide beam.

To measure depth, one takes the difference in time between the arrival of the signals on the cathode and anode side of the detector [5]. One can see in Fig. 1(b) that for this event the anode signal arrives before the cathode signal. This means that the interaction is closer to the anode side. A plot of the time difference between signals from ^{57}Co on the anode and cathode sides of the detector is shown in Fig. 2(a). The right hand side of the plot corresponds to the cathode side of the detector and the width of the distribution is $\sim$100 ns. The deviations at the edges are most likely due to changes of the electric field lines in the vicinity of the contacts.

To determine the lateral location of the interaction to less than the strip pitch requires measuring the induced charge in the neighboring strips. Observing Fig. 1(b), one sees that the signal induced in one neighboring strip is larger than the other. The simple assumption is that the interaction occurred closer to the strip with larger induced signal. To measure this effect, the difference between the integral of the induced signals over the sum of the integrals is plotted for two positions on the strip separated by 0.5 mm (see Fig. 3). The difference between the position of the peaks for the two positions and the width of the peaks yields a resolution of 0.4 mm FWHM. Subtracting in quadrature the beam size of 0.26 mm yields a resolution of 0.3 mm or about a third of the strip pitch. The track length is reduced for lower energies. Near the cathode face the induced signals are gone within 3-4 ADC samples because of electrons have higher velocity than the holes.

References

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